The Condor 92:220–228

THE VARIETY AND NUTRITIONAL VALUE OF FOODS CONSUMED BY HAWAIIAN CROW NESTLINGS, AN ENDANGERED SPECIES[1]

HOWARD F. SAKAI[2]
U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station, Institute of Pacific Islands Forestry, Honolulu, HI 96813

JAMES R. CARPENTER
University of Hawaii at Manoa, Department of Animal Sciences, 1800 East-West Road, Honolulu, HI 96822

Abstract. Research was conducted to determine the food habits of Hawaiian Crow (*Corvus hawaiiensis*) nestlings, variety of food items ingested relative to their age, and the nutritional composition of ingested fruits. Knowledge of the fruits' nutritive value and the nestlings' diet allowed us to determine what plants best meet nutritional needs of adult and nestling crows for restocking purposes. Our evaluation of fecal droppings suggested that nestlings were fed a variety of items similar to those ingested by adults. The types and proportions of food materials found in droppings changed with age. Crow nestlings' consumption of olapa (*Cheirodendron trigynum*) and oha-kepau (*Clermontia* spp.) fruits, passerine nestlings, and a variety of arthropods made up the highest percentage of food items found in droppings. Food items eaten by Hawaiian Crow nestlings generally had a high water content but varied greatly in nutrient density. Crude protein ranged from 1.81% in the hoawa (*Pittosporum hosmeri*) seed shell to 16.32% in the aiea (*Nothocestrum longifolium*) fruit. Fat content, gross energy content, fiber fractions, total digestible nutrients, digestible energy, metabolizable energy, and mineral levels varied greatly among fruit types. In general, the higher the fat content, the higher the energy density, and the lower the fiber fraction.

Key words: Hawaiian Crow; Corvus hawaiiensis; *nestling; food habits; nutrition; Hawaii.*

INTRODUCTION

Little is known of the diet of nestling Hawaiian Crows (*Corvus hawaiiensis*) and nothing is known of the nutritional properties of their foods. The few reports of nestlings' diet have been based on qualitative sightings of adult crows feeding their young at nest sites (Perkins 1903, Banko 1974, Giffin 1978). Recent studies (Giffin 1983, Sakai et al. 1986) have shown that fruits constitute 33%–46% of the adult's diet. Fruits are collected primarily from small trees or shrubs of the understory and mid-canopy (Sakai et al. 1986) which are often destroyed by agricultural or residential developments.

A detailed documentation of the types of foods eaten by Hawaiian Crow nestlings, along with some knowledge of their nutritional properties, will greatly enhance both existing information and our understanding of their food and habitat requirements. These factors are considered critical for maintaining the species' survival. The objective of this study was to provide a detailed account of food items eaten by Hawaiian Crow nestlings by paying particular attention to: (1) variety of foods ingested relative to age; and (2) relation of food availability to frequency of consumption, and nutritional composition.

METHODS AND STUDY AREA

Researchers studying nestling food habits of other corvids have analyzed stomach contents (Yom-Tov 1975) or food extracted from throats of nestlings fitted with neck collars (Owen 1956, Lockie 1959, Coleman 1971). Neither of these methods was used in this study because of the precarious locations and heights of nests (Sakai and Ralph 1980) and to minimize nest disturbances (Owen 1956). Fecal droppings were collected from nest

[1] Received 3 August 1989. Final acceptance 1 November 1989.

[2] Present address: U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.

sites at Honaunau Forest Reserve and McCandless Ranch in South Kona District, island of Hawaii. The foraging ecology of the adult Hawaiian Crow, a description of study sites, and methods used to measure seasonal fruiting and flowering has been previously published (Sakai et al. 1986).

Hawaiian Crows start nest building in early April, lay eggs in mid-to-late April and hatch young in early to mid-May. Usually fledging occurred in the later part of June to mid-July, but in successful renesting attempts fledging occurred in late July (D. Jenkins, pers. comm.).

We studied five nests in 1979 and two in 1980. Fecal droppings were collected from and below each nest site at least 2 days per week from day 14 of the 40-day nestling cycle. These seven nests represented half of all known Hawaiian Crow breeding pairs. Sixty-six fecal droppings representing each of three sampling periods (2- to 3-week-old [May 22–May 31], 3- to 4-week-old [June 1–June 20], and 4- to 6-week-old [June 21–July 15] nestlings) were analyzed using methods outlined by Ralph et al. (1985). Because fruit seeds passed through the crows' digestive tracts intact, we feel that fecal droppings provided a reliable means of assessing plant use.

Fruit samples were collected near foraging and nesting sites. Dates of fruit sampling were determined by availability of fruits and flowers. We kept samples on ice and transported them to the laboratory to be frozen for storage. Upon thawing, we dried samples in a convection oven at 50°–55°C for 5 to 7 days to obtain dry matter content. We then ground these samples through a 1-mm mesh stainless steel screen in a Wiley mill, and analyzed for crude protein (CP) and crude fat or ether extract (EE) following methods outlined by the Association of Official Analytical Chemists (1975). We obtained gross energy (GE) values by complete combustion in a Parr adiabatic calorimeter. We used procedures of Goering and van Soest (1970) to analyze for fiber components, acid detergent fiber (ADF), cellulose, and permanganate lignin (PL). We used the ADF values to calculate total digestible nutrient (TDN) level of the various fruits using the Cornell formula for mixed concentrates (%TDN = 81.41 − [(ADF/100) × 48]). The TDN value was then used to calculate digestible energy (DE [kcal/kg] = %TDN × 0.04409) which in turn was used to calculate metabolizable energy (ME). The formula we used was ME (kcal/kg) = DE(96 − [0.202 × %CP]/100). Minerals were analyzed by X-ray quantometer.

TABLE 1. Frequency of occurrence[1] (%) of food items in fecal droppings of 2-week-old and older Hawaiian Crow nestlings in Honaunau Forest Reserve and McCandless Ranch in the South Kona District, Island of Hawaii.

Species	Age of nestlings (weeks) 2–3	3–4	4–6
Fruit			
Akala (*Rubus hawaiiensis*)	14	26	29
Aiea (*Nothocestrum longifolium*)	0	3	51
Hoawa (*Pittosporum hosmeri*)	0	0	10
Ieie (*Freycinetia arborea*)	33	40	0
Kanawao (*Broussaisia arguta*)	0	1	0
Mamaki (*Pipturus* spp.)	6	36	5
Manono (*Gouldia terminalis*)	3	8	7
Oha kepau (*Clermontia* spp.)	30	94	100
Ohelo (*Vaccinium* spp.)	3	9	0
Olapa (*Cheirodendron trigynum*)	62	84	100
Passerine bird part and egg	52	91	83
Mammal			
House mouse (*Mus musculus*)	0	1	10
Seed			
Koa (*Acacia koa*)	2	0	5
Invertebrate			
Arachnida	59	75	22
Isopoda	32	51	78
Diplopoda	0	3	10
Gastropoda	2	4	2
Psyllidae	11	16	2
Delphacidae	2	0	2
Lepidoptera	48	58	39
Nabidae	35	52	12
Coleoptera	23	51	37
Diptera	8	32	32
Hymenoptera	23	26	20
Homoptera	2	6	0
Neuroptera	14	17	0
Hemiptera	6	5	2
Unknown insect	12	3	15

[1] Determined as total number of samples in which the diet item occurred divided by total droppings sampled.

RESULTS

VARIETY OF NESTLINGS' FOOD

Types of food items found in droppings suggest that nestlings were fed a variety of food items (Table 1) and were omnivores like adults (Sakai et al. 1986). Older aged nestlings ingested a higher proportion of passerine nestlings, the majority of invertebrates, eggs, and house mice, all higher in protein content than fruit. Although we collected no fecal droppings until day 14 we believe

TABLE 2. Nutritional properties of various fruits eaten by adult and nestling Hawaiian Crows or available for consumption in forest habitats in South Kona, Hawaii.

Species Plant part	Month sampled	% dry matter	% water	Gross energy kcal/g DM	% dry matter Crude protein	Ether extract	ADF	Cellulose	Lignin	TDN	DE	ME	Protein/ME
Aiea (*Nothocestrum longifolium*)													
Fruit	Jun	16.53	83.47	4.62	14.49	5.54	32.52	20.94	12.02	65.80	2.95	2.81	5.16
Fruit	Jul	16.86	83.14	4.57	16.32	6.39	28.37	17.14	11.39	67.79	3.04	2.89	5.65
Akala (*Rubus hawaiiensis*)													
Fruit	Apr	11.45	88.55	4.73	6.63	2.75	46.65	34.51	11.62	59.02	2.65	2.53	2.62
Fruit	Mar	16.54	83.46	4.79	8.06	2.75	46.65	34.51	11.62	59.02	2.65	2.53	3.19
Fruit	Jun	10.17	89.83	4.58	7.39	4.32	31.91	22.96	9.36	66.09	2.97	2.83	2.61
Alani (*Pelea* spp.)													
Green seeds	Mar	15.39	84.61	—	7.25	—	—	—	—	—	—	—	—
Brown seeds	Jun	33.82	66.18	4.44	8.34	2.07	72.87	67.34	5.60	46.43	2.08	1.98	4.20
Banana poka (*Passiflora mollissima*)													
Fruit	Jul	16.06	83.94	—	6.76	—	40.76	34.09	6.87	61.84	2.77	2.62	2.58
Hai wala (*Cyrtandra* spp.)													
Fruit	Jul	5.95	94.05	4.27	8.08	—	—	—	—	—	—	—	—
Hoawa (*Pittosporum hosmeri*)													
Green seeds	Apr	35.85	64.15	5.31	10.30	7.95	40.26	16.60	23.38	62.09	2.79	2.66	3.88
Green seeds	Jun	41.47	58.53	5.34	9.55	8.71	33.87	16.69	17.19	65.15	2.87	2.70	3.54
Brown seeds	Apr	43.65	56.35	5.34	11.31	10.98	41.26	19.15	21.91	61.61	2.77	2.63	4.30
Brown seeds	Jun	47.08	52.92	5.42	11.47	13.07	44.02	23.13	20.59	60.28	2.71	2.58	4.45
Shell	Mar	44.71	55.29	4.50	1.81	1.37	54.93	38.02	16.77	55.04	2.47	2.37	0.76
Hoi kuahiwi (*Smilax* spp.)													
Fruit	Jul	26.27	73.73	4.65	7.42	8.61	27.52	19.87	7.61	68.20	3.06	2.92	2.54
Ieie (*Freycinetia arbora*)													
Fruit	May	19.07	80.93	—	6.47	—	26.28	16.51	9.39	68.79	3.03	2.87	2.25
Kanawao (*Broussaisia arguta*)													
Fruit	Mar	17.31	82.69	4.09	5.22	0.88*	43.98*	16.53*	27.16*	60.30	2.71	2.59	2.02
Fruit	Apr	16.84	83.16	4.33	5.17	0.58*	43.98*	16.53*	27.16*	60.30	2.71	2.57	2.01
Kawau (*Ilex anomala*)													
Fruit	Mar	21.37	78.63	4.59	3.50	3.82*	43.27*	26.21*	16.98*	60.64	2.72	2.61	1.34
Fruit	Jun	18.40	81.60	4.60	2.62	3.82*	43.27*	26.21*	16.98*	60.64	2.72	2.61	1.00

TABLE 2. Continued.

Species Plant part	Month sampled	% dry matter	% water	Gross energy kcal/g DM	% dry matter Crude protein	Ether extract	ADF	Cellulose	Lignin	TDN	DE	ME	Protein/ME
Kolea (*Myrsine lessertiana*)													
Fruit, green	Jun	16.43	83.57	4.78*	7.05	15.80	34.29	16.00	18.37	64.95	2.92	2.79	2.53
Fruit, ripe	Apr	38.07	61.93	4.78*	4.54	8.95	—	—	—	—	—	—	—
Flower	Mar	24.39	75.61	5.92	8.53	—	—	—	—	—	—	—	—
Kopiko (*Psychotria* spp.)													
Fruit	Jul	24.45	75.55	—	10.75	—	40.92	27.13	14.40	61.77	2.77	2.64	4.07
Mamaki (*Pipturus* spp.)													
Fruit	May	7.23	92.77	3.95	7.63	1.34*	39.54*	19.81*	13.13*	62.43	2.80	2.68	2.85
Fruit	Jun	8.54	91.46	3.61	8.78	1.34*	39.54*	19.81*	13.13*	62.43	2.80	2.67	3.28
Manono (*Gouldia terminalis*)													
Fruit	Mar	18.46	81.54	4.40	5.50	2.03*	39.62*	25.40*	13.98*	62.39	2.80	2.68	2.05
Fruit	Apr	16.42	83.58	4.30	5.66	2.03*	39.62*	25.40*	13.98*	62.39	2.80	2.68	2.11
Fruit	Jul	15.27	84.73	4.09	3.41	2.53	31.81	20.60	11.41	66.14	2.97	2.84	1.20
Ma oi oi (*Stenogyne* spp.)													
Fruit	May	27.38	72.62	4.85	7.14	3.47	55.26	40.76	13.98	54.89	2.46	2.35	3.04
Naio (*Myoporum sandwicensis*)													
Fruit	Jun	30.98	69.02	—	2.17	—	48.48	39.47	9.18	58.14	2.61	2.50	0.87
Oha (*Cyanea* spp.)													
Fruit	Jun	17.29	82.71	—	6.25	—	27.56	18.17	8.47	68.18	3.01	2.85	2.19
Oha-kepau (*Clermontia* spp.)													
Fruit	Mar	12.75	83.92	4.34	8.44	1.59	30.03	23.98	6.64	67.00	2.95	2.78	3.04
Fruit	Jul	9.98	90.02	4.22	8.61	4.47	30.03*	23.98*	6.64*	67.00	3.01	2.87	3.00
Ohe (*Tetraplasandra meiandra*)													
Fruit	Mar	22.03	77.97	4.14	7.25	3.20	31.50	15.54	66.29	2.98	2.84	2.55	2.84
Ohelo (*Vaccinium* spp.)													
Fruit	Apr	14.06	85.94	4.79	6.78	3.26	53.15	41.03	12.03	55.90	2.51	2.38	2.85
Ohia (*Metrosideros collina*)													
Leaf bud	Apr	30.85	69.15	4.26	8.59	1.24	40.40	34.78	5.85	62.01	2.78	2.66	3.23

TABLE 2. Continued.

Species Plant part	Month sampled	% dry matter	% water	Gross energy kcal/g DM	% dry matter: Crude protein	Ether extract	ADF	Cellulose	Lignin	TDN	DE	ME	Protein/ME
Olapa (*Cheirodendron trigynum*)													
Fruit	Apr	29.32	70.68	5.22	6.87	13.80	37.80	28.54	9.17	63.27	2.84	2.71	2.53
Fruit	Jun	28.67	71.33	5.26	6.10	14.01	39.34	30.01	9.07	62.53	2.76	2.62	2.33
Fruit	Jul	31.17	68.83	5.23	6.52	13.80	33.50	26.16	7.63	65.33	2.93	2.80	2.33
Olomea (*Perrottetia sandwicensis*)													
Fruit	Jun	10.87	89.13	—	4.82	—	27.19	22.91	4.49	68.36	3.07	2.94	1.64
Painui (*Astelia menziesiana*)													
Bulb	Jun	11.48	88.52	4.02	6.81	1.45	40.56	26.45	13.19	61.94	2.78	2.66	2.56
Fruit	Jul	12.19	87.81	—	6.48	—	—	—	—	—	—	—	—
Pilo (*Coprosma* spp.)													
Fruit	Mar	30.15	69.85	4.70	4.62	2.51	48.27	33.23	14.89	58.24	2.61	2.50	1.85
Plum (*Prunus* spp.)													
Fruit	Jul	12.43	87.57	4.48	2.80	0.75	17.27	13.48	3.67	73.12	3.28	3.15	0.89
Poha (*Physalis peruviana*)													
Fruit	Sept	21.14	78.86	—	10.66	—	17.90	12.23	5.94	72.82	3.27	3.12	3.42
Pukiawe (*Styphelia* spp.)													
Fruit	Mar	31.25	68.75	4.80	1.95	3.4*	—	—	—	—	—	—	—
Fruit	Apr	24.10	75.90	4.75	2.37	3.4*	46.14	35.46	10.98	59.26	2.66	2.55	0.93
Southern pokeberry (*Phytolacca octandra*)													
Fruit	Mar	24.60	75.40	5.15	11.00	5.47	43.08	29.55	13.59	60.73	2.73	2.60	4.24
Fruit	Jul	21.12	78.88	4.94	12.02	5.00	—	—	—	—	—	—	—
Thimbleberry (*Rubus rosaefolius*)													
Fruit	Mar	16.36	83.64	4.62	7.96	4.96*	49.52*	35.77*	14.41*	57.64	2.59	2.47	3.22
Fruit	Jun	13.10	86.90	4.99	6.86	4.96*	49.52*	35.77*	14.41*	57.64	2.59	2.47	2.78

* Ether extract and/or fiber analyses were done on composite samples within each plant species.

1-week-old and younger nestlings were fed a varied diet similar to older nestlings. Hawaiian Crows increased their feeding activity on woody substrates and on flowers following the first week of hatching as reported by Sakai et al. (1986, p. 215). On 44 different occasions, adults were observed flying directly to feed their 1-week-old young after feeding on ohia (scientific names are found in Table 2) flowers, and on 29 different occasions after probing on woody substrates, possibly foraging for invertebrates.

FOOD AVAILABILITY AND CONSUMPTION

Occurrence of food items in the droppings of nestlings (Table 1) shows little relation to availability (Sakai et al. 1986, p. 215). For example, fruits like ieie and mamaki were not abundant during May and June (Sakai et al. 1986), yet nestlings were fed these fruits in greater frequency than more commonly available fruits. Aiea was an uncommon plant, but seeds were common in fecal droppings during July. However, passerine nestling remains (feathers and bones) and seeds of oha-kepau and olapa fruits were common in droppings in June and July (week 3–6), suggesting that these food items were used because of their abundance during these periods or their nutritional properties.

NUTRITIONAL PROPERTIES

Food items eaten by Hawaiian Crow nestlings generally had a high water content and varied greatly in nutrient density (see Tables 2, 3). The percentage of dry matter ranged from 5.95% in hai wala to 47.08% in hoawa with most fruits being between 10% and 20% dry matter. Like fruits and grains consumed by humans, wild fruits were low in protein. Crude protein content ranged from 1.81% in the hoawa seed shell to 16.32% in the aiea fruit. Most fruits contained less than 12–18% protein, which is needed by most domestic replacement pullets and laying hens (National Research Council 1984). Therefore, we believe that insects, bird nestlings, and field mice may have been consumed to meet protein needs. The hoawa seed shell was low in protein, but the green and ripe seeds were higher in protein than most of the other fruits. The aiea and hoawa, both high in protein, were consumed in greater quantities when the Hawaiian Crow nestlings were 4–6 weeks of age. Ether extract (or fat content), gross energy content, fiber fractions, calculated energy densities (total digestible nutrients, digestible energy, and metabolizable energy), and mineral levels also varied greatly among fruit types. In general, the higher the fat content the higher the energy density and the lower the fiber fractions (Table 2). All of the protein : metabolizable energy ratios (0.87 to 5.65) were lower than levels which are typical of most commercially prepared diets for poultry (6.25–7.50). The majority of sampled fruits contained more fiber fractions than typical poultry rations (20%–40% ADF in the fruits compared to 5%–9% in barley or corn grain). The ME levels were also lower than 2.9 kcal/kg dry matter which is needed by most domestic poultry throughout their life cycle (National Research Council 1984). These nutrient qualities could explain the greater use of olapa and oha-kepau fruits by adults (Sakai et al. 1986, p. 215) and by nestlings during summer breeding periods (Table 1). Mineral profiles for these ingested fruits showed that the mineral concentrations, except for calcium and phosphorus, were in line with needs of most domestic poultry (National Research Council 1984). Most fruits contained less minerals than needed by crows. There was extreme variation in the calcium-phosphorus ratio which generally, with exception of the laying bird, should run between 1.5 and 2.0 (National Research Council 1984). Plant parts (ohia leaf bud, kolea flower, and pain-ui bulb) eaten by adult Hawaiian Crows (Sakai et al. 1986, p. 213), and possibly fed to nestlings, were analyzed for crude protein and water content (Table 2) and in one case percentage of fat, however, results were inconclusive in explaining their use. We suspect that insects associated with ohia leaf buds and kolea flowers were probably the contributing factor in the crow's consumption of these plant parts.

DISCUSSION

Amount of protein food consumed by Hawaiian Crow nestlings generally increased as the birds matured, and this was contrary to Lockie's (1959) findings for Rooks (*Corvus frugilegus*) in England. This difference in the diet of Hawaiian Crow nestlings and congener species abroad suggests to us that both species are generalists, foraging on available food types. Climatic factors were shown to alter the feeding habits of young Rooks in England (Lockie 1959). However, Hawaii's semitropical climate provides an ideal situation for the production of native fruits throughout much of the year. Although phenol-

TABLE 3. Mineral properties of fruits eaten by adult and nestling Hawaiian Crows or simply available in forest habitats in South Kona, Hawaii.

Species	Plant part	Month sampled	% Ca	P	Mg	K	Na	ppm Mn	Fe	Cu	Zn	Ca:P ratio
Aiea	Fruit	Jun	0.28	0.22	0.23	1.82	0.24	14	46	12	21	1.27
	Fruit	Jul	0.21	0.22	0.21	2.29	0.26	11	53	11	19	0.95
Akala	Fruit	Jun	0.20	0.16	0.20	1.00	0.10	55	35	11	23	1.25
Alani	Fruit, brown	Jun	0.19	0.19	0.13	1.70	0.11	45	143	7	22	1.00
Banana poka	Fruit	Jul	0.60	0.09	0.10	2.00	0.70	12	150	39	20	6.67
Hoa kuahiwa	Fruit	Jul	0.60	0.14	0.20	1.50	0.40	75	65	17	19	4.29
Hoawa	Fruit, green	Apr	0.40	0.36	0.30	1.20	0.10	45	105	14	34	1.11
	Fruit, green	Jun	0.30	0.34	0.30	0.90	0.30	22	120	18	34	0.88
	Fruit, brown	Jun	0.40	0.34	0.30	0.50	0.20	30	65	18	36	1.18
	Fruit/shell	Mar	0.30	0.03	0.10	0.60	0.70	20	65	9	26	10.00
Ieie	Fruit	May	1.10	0.12	0.30	1.20	0.60	20	125	30	26	9.17
Kanawao	Fruit	Apr	0.90	0.15	0.20	0.70	0.40	50	45	12	12	6.00
Kawau	Fruit	Mar/Jun	0.50	0.08	0.20	0.60	1.10	55	60	9	22	6.25
Koa	Flower	Mar	0.30	0.21	0.20	1.10	0.09	40	45	36	38	1.43
Kolea	Fruit, green	Jun	0.30	0.15	0.10	1.10	0.70	13	195	7	16	2.00
Kopiko	Fruit	Jul	0.66	0.15	0.22	1.82	0.22	41	66	8	18	4.40
Mamaki	Fruit	May	3.51	0.22	0.47	1.45	0.07	64	56	17	36	15.95
Mamane	Flower	May	0.40	0.27	0.20	1.50	0.06	25	130	26	40	1.48
Manono	Fruit	Jul	1.80	0.12	0.50	1.20	0.50	325	160	8	26	15.00
Ma oi oi	Fruit	May	0.14	0.13	0.11	1.50	0.11	15	138	14	13	1.08
Naio	Fruit	Jun	0.30	0.12	0.07	0.96	0.30	9	10	6	17	2.50
Oha-kepau	Embryo	Mar	0.42	0.26	0.26	1.58	0.27	66	75	13	27	1.62
	Fruit, shell	Mar	0.54	0.14	0.23	3.32	0.25	47	69	11	32	3.86
Ohelo	Fruit	Apr	0.24	0.12	0.08	0.88	0.03	88	279	10	14	2.00
Ohia	Leaf bud	Apr	0.20	0.18	0.10	0.80	0.20	25	225	16	20	1.11
Olapa	Fruit	Apr	0.80	0.13	0.20	1.80	0.06	105	55	10	28	6.15
	Fruit	Jun	1.00	0.16	0.20	2.00	0.10	120	95	12	30	6.25
Olomea	Fruit	Jun	0.70	0.14	0.20	1.20	0.20	8	0	10	21	5.00
Painui	Bulb	Jun	0.80	0.15	0.20	2.40	0.40	110	105	11	32	5.33
Pilo	Fruit	Mar	0.49	0.10	0.13	1.25	0.08	71	44	11	22	4.90
Plum	Fruit, ripe	Jul	0.10	0.11	0.05	1.00	0.07	6	35	6	10	0.91
Poha	Fruit, ripe	Sept	0.08	0.44	0.20	1.80	0.08	12	65	16	55	0.18
Pukiawe	Fruit, ripe	Apr	0.20	0.03	0.03	0.20	0.06	85	105	4	6	6.67
Southern pokeberry	Fruit	Mar	0.14	0.23	0.19	2.44	0.22	313	53	9	23	0.61
Thimbleberry	Fruit	Mar	0.20	0.18	0.21	1.51	0.09	16	76	9	26	1.11

ogy data are lacking from August through December (Sakai 1986, p. 215), we believe that certain fruits like ieie, pilo, naio, hoawa, and kawau will be available during portions of these periods. Therefore, if these fruiting plants are available in sufficient densities during these periods, food availability may not be a factor in the population decline. Since adults and nestlings are food generalists, they should encounter no difficulty in switching to other food sources. Hawaiian Crow nestlings were fed available food resources as demonstrated by the common occurrence of bird remnants in their droppings. In this case, the breeding season of Hawaiian Crows is synchronous with that of other passerine species (Berger 1981) that nest in the study area.

Types of foods eaten by Hawaiian Crow nestlings were similar to congeneric crow nestlings.

Mammals, birds, unidentified meat, arthropods (Hymenoptera, Diptera, Coleoptera, Lepidoptera, Tipulidae, Arachnida, and Hemiptera), wild fruits, bird eggs, gastropods, and seeds were also reported by Yom-Tov (1975), Coleman (1971), Lockie (1959), and Holyoak (1968). This wide array of available foods suggests that adult Hawaiian Crows are no different than congeneric species in providing nourishment for their young.

Present status of the population looks dismal: only one known breeding pair remains in the wild and five breeding pairs live in captivity (J. M. Scott, pers. comm.). If this species is to escape extinction, its fate lies with the ongoing captive propagation program. However, before captive reared crows can be reintroduced to their "natural" habitat, measures directed at alleviating known limiting factors, as discussed by Giffin et al. (1987), must be addressed. They believe that preserves are vital for the success of the captive propagation program, and they discuss the concept of establishing preserves as a means of saving remaining suitable habitat. We agree with Giffin et al. (1987, p. 493) concerning the importance of restoring native food plants in established preserves. We believe, however, that when preserves are being planned, emphasis should be placed on planting or maintaining fruit-producing trees that provide optimum nutritive properties for crows throughout the year. For example, extensive use of olapa drupes during the breeding season by adults (Sakai et al. 1986, p. 215) and nestlings (Table 1) may occur because of its high fat content, mineral properties, and easy accessibility. Although aiea is uncommon (Sakai et al. 1986, p. 212), evidence of its use was found in the droppings during the later nestling stages. We hypothesize that aiea fruits were extensively used because of their high crude protein content. Extensive use of oha-kepau fruits can be simply explained by their abundance in our study areas (Sakai et al. 1986, p. 212), and to their high crude protein content. Fruits like alani and hoawa are good sources of crude protein, but they were used less frequently, possibly because of the amount of energy required to pry open the hard outer shell (Sakai et al. 1986, p. 217). However, these fruits remain on trees for a longer period than fleshy fruits and are, therefore, available for a longer period of time. Crows have been observed to feed on the nonnative banana poka (P. C. Banko, pers. comm.; Giffin 1975), but since these plants are noxious and will eventually cause death to host trees by smothering the canopy, they should not be considered as a food source for Hawaiian Crows.

The Hawaiian Crow spends spring and summer at higher elevations than in fall and winter (Giffin et al. 1987). They suggested that seasonal movement may reflect food availability, as it corresponded with the peak food-plant fruiting periods at each location. Olapa and oha-kepau are common summer foods above 1,100 m elevation, whereas the ieie and mamaki are principal winter foods and are most common below 1,100 m elevation (Rock 1913, Giffin 1983). More recently, vegetation analysis of dry-forest plots (Scott et al. 1986) showed only 35% of wet-forest plot values for those fruit-bearing genera that the Hawaiian crow is likely to eat. Assuming an appropriate site and plant species are selected, our results indicate that fruits can be made available year-round for crows in managed forests. The benefit of having food resources available year-round is that crows can remain in the managed area throughout the year, thus eliminating pressures from shooting, nest disturbances, and exposure to diseases (providing that preserves are located in mosquito-free zones). If managed forests are seriously being considered for upgrading existing crow habitat, then restocking measures should start immediately. Based on our estimates of nutritional content of known fruits eaten by nestlings, we recommend that the following native plants always be an integral part of the managed forest ecosystem: akala, aiea, alani, hoawa, ieie, kawau, kolea, kopiko, mamaki, naio, oha, oha-kepau, ohelo, olapa, and pilo.

ACKNOWLEDGMENTS

We thank the trustees of Bishop Estate, and William Rosehill and William Stayton for allowing us access to the forest and for their willingness to assist us. We also are grateful to Cynthia Sealy, manager and owner, who allowed access to McCandless Ranch. The following individuals helped in various ways: Wayne Gagne in classifying invertebrates found in droppings, and providing information on life history; Helen James and Quentin Tomich in identifying bones and fur found in droppings; Stephanie Nagata for processing droppings; Ruth Niino-DuPonte for sample preparation and ensuring that chemical analyses were completed and tabulated. We also thank Barry Noon, Ruth Niino-DuPonte, Michael Scott, Timothy Moermond, Robert Butler, and an anonymous reviewer for their helpful comments and assistance during preparation of this manuscript.

LITERATURE CITED

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official methods of analysis. 12th ed. Washington, DC.

BANKO, P. C. 1974. 'Alala investigation: report. Hawaii Dept. Land and Water Res., Div. Forestry and Wildlife, Honolulu, HI.

BERGER, A. J. 1981. Hawaiian birdlife. Univ. Press of Hawaii, Honolulu.

COLEMAN, J. D. 1971. The distribution, numbers, and food of the Rook *Corvus frugilegus frugilegus* in Canterbury, New Zealand. N. Z. J. Sci. 14:494–506.

GIFFIN, J. G. 1978. 'Alala investigation: report. Hawaii Dept. Land and Nat. Res., Div. Forestry and Wildlife, Honolulu, HI.

GIFFIN, J. G. 1983. 'Alala investigation: report. Hawaii Dept. Land and Nat. Res., Div. Forestry and Wildlife, Honolulu, HI.

GIFFIN, J. G., J. M. SCOTT, AND S. MOUNTAINSPRING. 1987. Habitat selection and management of the Hawaiian Crow. J. Wildl. Manage. 51:485–494.

GOERING, H. K., AND P. J. VAN SOEST. 1970. Forage fiber analysis. U.S.D.A., A.R.S. Agriculture handbook no. 379. Washington, DC.

HOLYOAK, D. 1968. A comparative study of the food of some British Corvidae. Bird Study 14:147–153.

LOCKIE, J. D. 1959. The food of nestling Rooks near Oxford. Br. Birds 52:332–334.

NATIONAL RESEARCH COUNCIL. 1984. Nutrient requirements of poultry. 8th ed. National Academy of Sciences, Washington, DC.

OWEN, D. F. 1956. The food of nestling Jays and Magpies. Bird Study 3:257–265.

PERKINS, R.C.L. 1903. Vertebrata, p. 365–466. *In* D. Sharp [ed.], Fauna Hawaiiensis, vertebrata. Cambridge Univ. Press, Cambridge, England.

RALPH, C. P., C. J. RALPH, AND S. E. NAGATA. 1985. Analysis of droppings to describe diets of small birds. J. Field Ornithol. 56:165–174.

ROCK, J. F. 1913. The indigenous trees of the Hawaiian Islands. Hawaiian Gazette, Honolulu.

SAKAI, H. F., AND C. J. RALPH. 1980. Observations of the Hawaiian Crow in South Kona, Hawaii. Elepaio 40:133–138.

SAKAI, H. F., C. J. RALPH, AND C. D. JENKINS. 1986. Foraging ecology of the Hawaiian Crow, an endangered generalist. Condor 88:211–219.

SCOTT, J. M., S. MOUNTAINSPRING, F. L. RAMSEY, AND C. B. KEPLER. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Stud. Avian Biol. 9:1–431.

YOM-TOV, Y. 1975. Food of nestling crows in Northeast Scotland. Bird Study 22:47–51.